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Report to Educators

The crew of Mission 51-L: (Front row Michael J. Smith, Pilot; Francis R. (Dick) Scobee, Commander; Ronald E. McNair, Mission Specialist; (Back row) Ellison S. Onizuka, Mission Specialist; S. Christa McAuliffe, Space Flight Participant (Teacher-Observer); Gregory B. Jarvis, Payload Specialist (Hughes Communications); Judith A. Resnik, Mission Specialist.

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Mission 51-L

On January 28, 1986, 73 seconds after launch at 11:38 a.m. EST, the flight of Space Shuttle Mission 51-L ended abruptly in an explosion. President Reagan delivered the following statement to the nation after the tragedy.

Ladies and gentlemen, I planned to speak to you tonight to report on the State of the Union, but the events of earlier today have led me to change those plans. Today is a day of mourning and remembering. Nancy and I are pained to the core by the tragedy of the shuttle *Challenger*. We know we share this pain with all of the people of our country. This is truly a national loss.

Nineteen years ago, almost to the day, we lost three astronauts in a terrible accident on the ground, but we've never lost an astronaut in flight; we've never had a tragedy like this. And perhaps we've forgotten the courage it took for the crew of the shuttle but they, the *Challenger* seven, were aware of the dangers and overcame them and did their jobs brilliantly.

We mourn seven heroes: Michael Smith, Dick Scobee, Judith Resnik, Ronald McNair, Ellison Onizuka, Gregory Jarvis, and Christa McAuliffe. We mourn their loss as a nation, together.

The families of the seven—we cannot bear, as you do, the full impact of this tragedy but we feel the loss and we're thinking about you so very much. Your loved ones were daring and brave and they had that special grace, that special spirit that says "Give me a challenge and I'll meet it with joy." They had a hunger to explore the universe and discover its truths. They wished to serve and they did—they served all of us.

We've grown used to wonders in this century; it's hard to dazzle us. For 25 years the United States space program has been doing just that. We've grown used to the idea of space, and perhaps we forget that we've only just begun. We're still pioneers. They, the members of the *Challenger* crew, were pioneers.

And I want to say something to the schoolchildren of America who were watching the live coverage of the shuttle's takeoff. I know it's hard to understand that sometimes painful things like this happen. It's all part of the process of exploration and discovery, it's all part of taking a chance and expanding man's horizons. The future doesn't belong to the fainthearted. It belongs to the brave. The *Challenger* crew was pulling us into the future and we'll continue to follow them.

I've always had great faith in and respect for our space program, and what happened today does nothing to diminish it. We don't hide our space program, we don't keep secrets and cover things up. We do it all up front and in public. That's the way freedom is and we wouldn't change it for a minute. We'll continue our quest in space. There will be more shuttle flights and more shuttle crew and, yes, more volunteers, more civilians, more teachers in space. Nothing ends here. Our hopes and our journeys continue.

I want to add that I wish I could talk to every man and woman who works for NASA, or who worked on this mission, and tell them: "Your dedication and professionalism have moved and impressed us for decades, and we know of your anguish. We share it."

There's a coincidence today. On this day 390 years ago, the great explorer Sir Francis Drake died aboard ship off the coast of Panama. In his lifetime the great frontiers were the oceans, and a historian later said, "He lived by the sea, died on it and was buried in it." Well, today we can say of the *Challenger* crew, their dedication was, like Drake's, complete. The crew of the space shuttle *Challenger* honored us by the manner in which they lived their lives. We will never forget them nor the last time we saw them this morning as they prepared for their journey and waved goodbye and "slipped the surly bonds of Earth to touch the face of God."

Thank you.

Teacher in Space Program

In February, NASA affirmed a plan to continue the educational programs developed in conjunction with the Teacher in Space Project.

The original and continuing goals of NASA's Educational Affairs Division are to increase the prestige of the teaching profession, to increase the awareness in the educational community of the impact of technology and science on this country's future, and to use space as a catalyst to enhance all subject areas and grade levels. These goals have been an inherent part of NASA's educational program since its education office was established in 1960.

The Teacher in Space Program represents an amplification of those goals. NASA's Educational Affairs Division, under the direction of Dr. Robert W. Brown, has received widespread support for the continuation of the program from teachers, students, educational organizations, the private sector, and the general public.

NASA plans include: (1) Barbara Morgan will assume a leadership role in the Teacher in Space Program from NASA Headquarters; (2) the eight Teacher in Space Project finalists will continue their efforts to promote the educational goals of the program; (3) the 103 Space Ambassadors, state finalists in the Project, have rededicated their commitment to take an active role in their respective states to motivate young people to expand their horizons in preparation for the future; (4) PBS and public television, strong advocates of the program, will continue to produce and disseminate educational materials about the space program; (5) the Teacher in Space *Teacher's Guide*, the concept-based activities designed to strengthen critical thinking and problem-solving skills, will be useful in conjunction with all Shuttle missions; (6) "Partnerships in Education," initiated with major national education associations, will be developed further.

Voyager 2 at Uranus—Early Findings

On January 24, 1986, *Voyager 2* once again expanded our awareness of our planetary neighborhood. For six hours the spacecraft sped past Uranus, its rings and moons, just 81,500 kilometers above the cloudtops. The lovely blue-green planet named for the Greek god of heaven, is no longer remote and mysterious. *Voyager's* encounter brought the Uranian system close. Like Jupiter, Saturn, and their satellites before them, Uranus and its satellites have become familiar places.

The Uranus encounter period was divided into phases: observatory (Nov. 4, 1985-Jan. 10, 1986; far encounter (Jan. 10-22, 1986); near encounter (Jan. 22-26, 1986); and post encounter (Jan. 26-Feb. 25, 1986). Closest approach on January 24 was 9:59 a.m. PST, slightly more than a minute sooner than projected five years ago.

Voyager carried ten scientific instruments and a radio system. Four of the instruments were optical—the wide and narrow angle cameras, the ultraviolet spectrometer, the infrared interferometer, and the photopolarimeter. The other six measured properties of the space near the planet including its magnetic field, plasma, plasma waves, planetary radio emissions, low-energy charged particles, and cosmic rays. The radio system was used for scientific measurements as well as for communication with Earth.

Voyager's performance was flawless, and for scientists and engineers, its success, exhilarating. Uranus is so distant that it took 2 hours and 45 minutes for a radio signal to reach Earth from the planet during the close encounter. The Uranian system was relatively unknown and, therefore, the spacecraft was exploring a strange and mysterious environment. *Voyager's* remarkable imaging system—and no instruments were more exciting to scientists and public alike—sent back thousands of stunning images, and its experiments transmitted billions of bits of data on the properties of the planetary system. During the encounter we at least gained as much knowledge about Uranus as we've gained since its discovery by William Herschel in 1871. The new information will add immeasurably to our knowledge of the Solar System and Earth's place within it.

The encounter was also a challenge. Surprising results, unexpected answers to many questions, and new scientific mysteries yielded a rich return with scientists admitting to being "happily bewildered."

A course-correction maneuver has refined the spacecraft's flight path to Neptune, where it is scheduled to make the first closeup encounter in August 1989. *Voyager's* past performances make the anticipation of the next three and a half years great indeed.

The Planet

During the far encounter period, *Voyager* photographs showed a slight evidence of features in the atmosphere, and this data gave the first indication that Uranus has an active atmosphere. These early near encounter findings kept the promise of a wealth of new information.

Atmosphere. Uranus has a massive atmosphere. The two most abundant gases, hydrogen and helium, constitute about 84 to 88 percent and 12 to 16 percent of the atmosphere, respectively. A trace of methane in the atmosphere gives the planet its blue-green color.

A high altitude haze layer shows a banded structure that is concentric about the rotational pole; it may include polyacetylene hydrocarbons, possibly produced photochemically. The haze over the south polar region could be produced by the action of ultraviolet sunshine on the methane; this would produce acetylene which would, in turn, produce a weak photochemical smog.

Uranus has an extensive corona. On the dayside atmosphere, bright ultraviolet emissions from atomic and molecular hydrogen extend thousands of kilometers above the limb and across the sunlit disc. The hydrogen appears to absorb ultraviolet light from the Sun and reemit it in an amplified form. Scientists call the process, similar to emissions that were found at Jupiter and Saturn, electroglow. How the process works is one of the puzzles posed by *Voyager's* data. A high mid-thermosphere temperature, 150° to 750°K, which may result from heating by the mechanism responsible for the electroglow, implies a corona of atomic hydrogen.

There are winds on Uranus. Clouds in the Uranian atmosphere were detailed for the first time, tracked as they traveled about the planet at different speeds at different latitudes. The clouds are organized into bands running parallel to the equator, indicating winds blowing in the same direction as the planet rotates at speeds of 15 to 220 meters per second. Identifying and tracking specific features in the clouds helped determine Uranus' rotation rate.

The atmosphere at cloud-top level

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Time-lapse images of Uranus taken over a 4.6 hour interval on Jan. 14 show the rotational movement of two small, bright clouds. Voyager *was about 12.9 million km from the planet, whose pole of rotation is near the center of the disc. The clouds rotate in a counter-clockwise direction. The larger, brighter cloud is at a latitude of 33°; the smaller, seen faintly in the three images, lies at 26°. Their periods of rotation are 16.2 and 16.9 hours, respectively, which implies that the lower-latitude feature is lagging behind at almost 100 meters per second. Faint latitudinal bands are also visible in these images.*

rotates five percent faster than the interior. This differential rotation cannot be maintained by solar heating, but at present the mechanism for maintaining this differential rotation is unknown.

Temperature. Vertical temperature profiles have been deduced from the measured spectra in both polar regions and at many latitudes. The minimum temperature near the tropopause, the boundary between the troposphere (where life abounds on Earth) and the stratosphere, is about 52°K. There were surprises: the equatorial regions are as warm as the sunlit polar area; the dark pole is slightly warmer than the sunlit pole; the poles and most of the planet show nearly the same temperatures below the tropopause, except for a band between 15° and 40° latitude, where the temperatures are two to three degrees Kelvin lower and which corresponds to the region where cloud streaks were observed.

Magnetosphere. Before *Voyager's* flyby, the Earth-orbiting *International Ultraviolet Explorer* detected ultraviolet emissions from Uranus, which, if produced by an Aurora, would indicate that the planet might have a magnetic field. On January 19, the plasma wave investigation detected an intense radio burst and provided the first indication that Uranus has a magnetosphere.

Measurements of the hot plasma and radiation environments around and within the magnetosphere resulted in some important discoveries: the strength of Uranus' magnetic field at its equator is about the same as that of Saturn and Earth; the particles in the outer magnetosphere consist almost exclusively of ionized hydrogen; Uranus possesses radiation belts similar to Earth's Van Allen belts and the belts are of an intensity such that irradiation would quickly darken any methane ice on the surfaces of the Uranian ring particles and moons, contributing to their charcoal-dark appearance.

Not only does Uranus have a strong magnetic field, but the field has a peculiar orientation; the poles are tilted 57° from the planet's rotational axis, which is already tilted 8° below the ecliptic plane. The com-

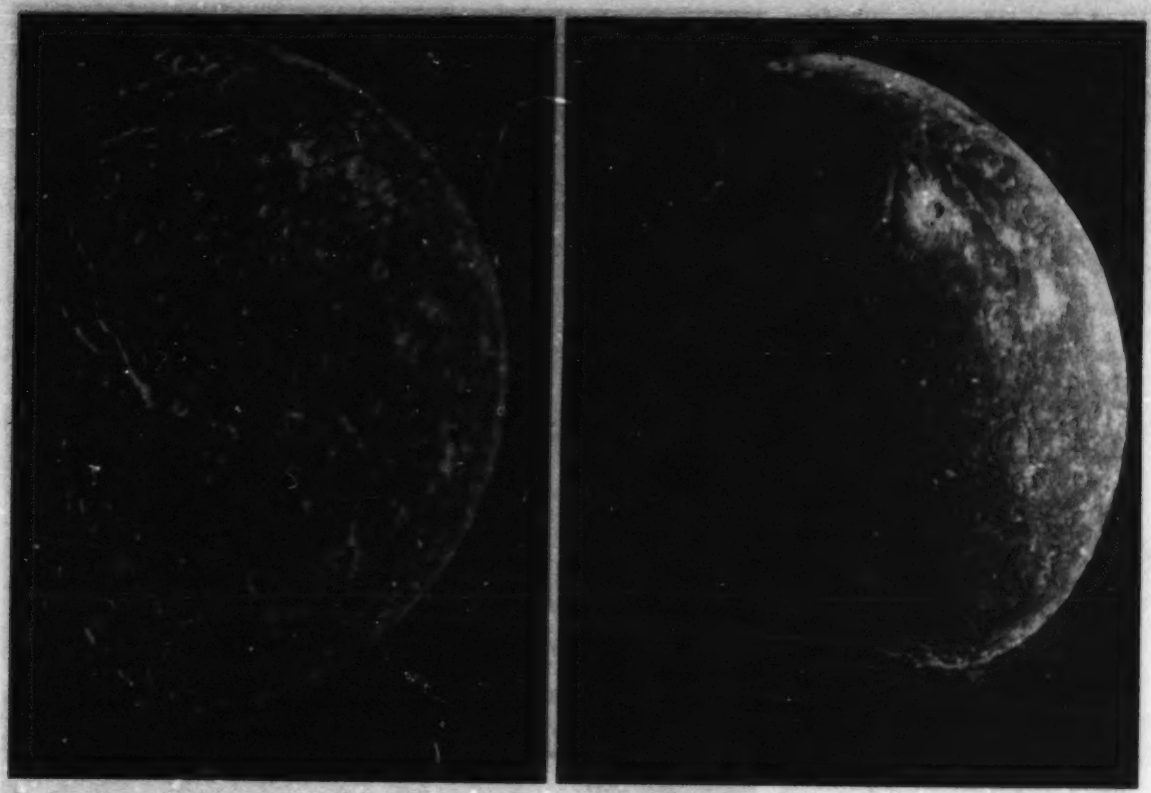
bined effect of the extreme tilt of the magnetic axis and that of the rotational axis is that the planet's magnetotail is swept about in space like a corkscrew.

The Rings

Preliminary results both confirm known data and add fundamental discoveries about the structure and composition of the ring system. (1) The Uranian system is distinctly different from that of Jupiter or Saturn. The nine charcoal-dark rings known from ground-based occultation measurements were detected and their interior structure delineated at a high spatial resolution. The optical thickness of the rings appears to vary significantly as the rings orbit the planet. (2) The rings are composed mostly of meter and larger-sized particles. (3) A tenth ring, designated 1986U1R, was found inside epsilon, the outermost known ring; in addition to the ten rings, ten pieces of rings, or arcs, were detected, some as small as 50 meters in width, and a ring appears to exist inside the innermost of the nine known rings. (4) Two tiny shepherding satellites flank the epsilon ring: first seen at Saturn, such moons are believed to be the mechanism that keeps ring material orbiting a planet. (5) The rings vary very slightly in color, an unexpected result that implies differing compositions of material in the several rings. (6) A complex structure, a tenuous distribution of fine dust, was found spread throughout the entire region of the known rings. The tiny dust particles may be formed by collisions between larger ring particles; the dust is thought to be being swept out of the ring system in some way.

The existence of the dust layer is leading to reexamination of current concepts of the origin and evolution of all three well-observed planetary ring systems. Understanding the processes responsible for ring structure will produce new insights into those that were probably active in the disc of particles that surrounded the Sun in the early days of the Solar System, processes that were important in the formation of the planets. Scientists believe the structure of Uranus' rings is attributable to the different conditions at the planet—

All nine of the known Uranian rings are visible in this image, which shows the two shepherding satellites associated with the epsilon ring, designated 1986U7 and 1986U8, on either side of the bright outer ring. The image was taken on Jan. 21 at a distance of 4.1 million km; resolution is about 36 km. (The dark halo surrounding the ring and occasional blips seen on it are the result of image-processing.) Lying inward from the epsilon ring are the delta, gamma, and eta rings; then the beta and alpha rings; and finally, the barely visible 4, 5, and 6 rings. Studied since their discovery in 1977, this is the first direct observation of all nine rings in reflected sunlight. They range in width from about 110 km at the widest part of the epsilon ring to only a few km for most of the others.



On Jan. 24, Voyager's narrow-angle camera took pictures of Ariel (left) from a distance of 130,000 km and Titania (right) from 369,000 km. The picture of Ariel is a mosaic of the four highest resolution (2.4 km) images. That of Titania is a composite of two images; the resolution is 13 km.

its peculiar tilt and that of its magnetic field, different composition of the ring material, and different types of interactions with the outlying satellites. Working out the dynamics of the ring structure, how it formed, how it persists, the mass distribution and spatial extent of the dust layer, will keep scientists busy for years.

The Satellites

Before the encounter, five moons were known to orbit Uranus—Miranda, Ariel, Umbriel, Titania, and Oberon. On December 31, 1985, a sixth, designated 1985U1, was discovered between the epsilon ring and Miranda, the innermost satellite. By January 13, six more had been found; designated 1986U1-1986U6 until formally named, they are located between the epsilon ring and 1985U1, which was the innermost moon known before their discovery. All six were found clustered about the same distance from the planet.

The tiny shepherd moons (20 to 30 km in diameter) found at the epsilon ring and designated 1986U7 and 1986U8, raised the total to 14. Another has been found and there may be still more in the *Voyager* data.

The Large Moons. *Voyager's* clear, high-resolution images of each of the five large Uranian moons left scientists astonished and the laity entranced. Though they had been observed from Earth, the moons as seen by *Voyager* were the biggest surprise of the encounter. Becoming more puzzling as the spacecraft approached, the images, upon preliminary analysis, show that the five are ice-rock mixtures with a wide diversity in appearance and apparent history. Ancient, heavily cratered surfaces appear on many of the satellites along with strong evidence of internal geologic activity, especially in those nearest Uranus. There are valleys the size of the Grand Canyon, crater floors that may have oozed icy slush. In some cases, the active internal processes seemed to have rapidly deposited material and resurfaced the satellites.

Ariel. Ariel's terrain is complex. Although its diameter is only about 1,200 km, it has already experienced a great deal of geological activity. The surface, densely pitted with craters five to ten kilometers across, is crisscrossed by numerous fault scarps and fault-bounded valleys (graben). The largest fault valleys, near the terminator at the right in the photograph are partly filled with younger deposits that are less heavily cratered. Narrow, somewhat sinuous scarps and valleys have been formed, in turn, in these young deposits. Bright spots near the limb and toward the left are chiefly the

Image of Miranda obtained by Voyager *on approach from 42,000 km. Its narrow-angle camera acquired this clear-filter view showing several regions of distinctly differing terrain—grooved areas with light and dark bands, the unusual bright V-shaped chevron figure, sinuous scarps that are probably faults, and, superimposed on both types of terrain, many bowl-shaped impact craters less than five km wide. The entire picture spans an area about 220 km across.*

rims of small craters; though the youngest features on Ariel, these bright-rimmed craters probably have formed over a long span of geological time.

Titania. Uranus' largest satellite has an abundance of impact craters of many sizes. The most prominent features are fault valleys that stretch to 1,500 km long and 75 km wide. The bright walls of the canyons seen in the picture indicate a lighter material, possibly young frost deposits. At the top is an impact crater perhaps 300 kilometers across; another almost as large is visible at the bottom of the disc.

Miranda. The smallest satellite was the most spectacular. *Voyager* passed by Miranda at a distance of 31,000 km, the closest approach the spacecraft has made to any body it has visited. Incredibly detailed pictures of superb quality show a planetary surface unlike any in the Solar System: up to ten different terrains include a rugged mix of valleys and broad terraces; old and new surfaces; scarps that range from .5 to 5 km in height; long ridges; a multitude of craters; glacial flows; and puzzling features that resemble a racetrack, a tilled field, and a bright chevron.

Called a hybrid of the most bizarre geologic forms in the Solar System, scientists were awestruck and described Miranda as exotic, extraordinary, and a fascinating riddle. Once again, answers have posed new questions.

Educators' Conference

As at the *Voyagers'* encounters with Jupiter and Saturn, an Educators' Conference was hosted by the Education Office of the NASA Jet Propulsion Laboratory in Pasadena, January 24-25. **Michael Garcia,** educational officer, guided some 300 participants through a program that included presentations on *Voyager*, future astronomy programs, the *Voyager* Encounter with Neptune Mission, the JPL Educational Outreach Program, and briefings during the encounter.

Among the attendees were the eight NASA student award-winners who won the trip with their teachers at the 36th International Science and Engineering Fair in May 1985.

The program also included a Planetary Society Symposium, "URANUS: The Voyage Continues," cosponsored by JPL. Moderated by astronomer Carl Sagan, the symposium panel included physicist Freeman Dysan; historian/astronomer Michael Hoskin; Bruce Murray, former director of JPL; and Edward Stone, Project Scientist for the Voyager mission.

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Where to Write for Services

Publication lists, film lists, and information about other services are available from the Education Services office at the NASA center serving your state. See the list below. There also are resource centers for educators at the Alabama Space and Rocket Center (Huntsville, AL 35807) and National Space Technology Laboratories (NSTL, MS 39529).

NASA Ames Research Center
Moffet Field, CA 94035
Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming

NASA Goddard Space Flight Center
Greenbelt, MD 20771
Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont

NASA Lyndon B. Johnson Space Center
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Muriel M. Thorne, Editor

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